Gas and dust
- Composition and shape
- Extinction
- Reddening
- Polarization

Emission Nebula
Dark dust clouds
21-cm radiation
Molecular clouds

Gas and Dust

Interstellar medium - the matter between the stars.

- Interstellar medium is made up of 2 components—gas and dust
- The gas is very cold (less than 100 K) and made up mainly of individual atoms and small molecules mainly hydrogen and helium.
- The dust consists of clumps of atoms and molecules (like the ones that make up smoke or soot).

The Interstellar Medium

Milky Way: vast field of stars as well as dark regions due to interstellar dust.
Photo credit: Gary A. Baker

blocking of light (by Gas and Dust)

Interstellar matter blocks the light from stars.
- Obscuration (blocking) is caused mainly by dust particles also called dust grains.
- Light can be obscured (absorbed or scattered) only by particles having diameters comparable to or larger than the wavelength of radiation involved.
- The size of typical dust grain is ~ $10^{-7}$ m (0.1 µm), comparable in size to the wavelength of visible light. So dust grains try to block the visible light.
- Obscuration produced by particles of a given size increases with decreasing wavelength (increasing frequency). So, Ultra violet, X-rays and Gamma rays etc. are blocked even more by Dust grains. But infrared and radio waves can pass through.

Consequences...

Extinction:

Reddening: as mentioned previously that the dust preferentially absorbs short-wavelength radiation. Because of this, blue part of light from distant stars is obscured more than red. So in addition to being generally diminished in overall brightness, stars also appear redder than they really are. This effect is know as reddening.
**Density of the Interstellar Matter**

**Gas and Dust**

- Interstellar matter (gas and dust) is found everywhere in interstellar space but not distributed uniformly.
- Overall density of the interstellar medium is very low:
  - The gas averages roughly $10^6$ atoms per cubic meter—just one atom per cubic centimeter (much less than best vacuum attained in labs).
  - Interstellar dust is even rarer—about one dust particle for every trillion or so gas atoms.

*So, how come... such a sparse matter is able to block light?*

**Composition of the Interstellar Matter**

**Gas and Dust**

- **Gas:** (composition is more or less like stars or jovian planets.)
- **Dust:**

  - Infrared observations indicate for silicates, carbon, and iron, supporting the theory that interstellar dust forms out of interstellar gas.
  - There is also an indication for some “dirty ice,” a frozen mixture of water ice contaminated with trace amounts of ammonia, methane, and other compounds.

**Shape of the Interstellar Matter**

**Gas and Dust**

- **Gas:**
- **Dust:**

Light is an electromagnetic radiation (combination of electric and magnetic field) and travels in a random orientation.

But due to the shape of dust particles, sometimes light rays become aligned with all the electric field vibrating in the same plane. This is called...
Charles Messier, 18th century French astronomer saw sky much like this figure.

He observed several fuzzy patches of light that he could not classify as stars, planets, comets, or asteroids. So, they were named as nebulae.

Emission Nebulae

Emission Nebulae are among the most spectacular objects in the entire universe.

Nebulae large enough to measure size with simple geometry.

Emission Nebulae

Emission spectrum produced by them allow us to measure their properties:

• UV radiation from a forming O- or B-type star ionizes surrounding nebular gases.
• As hydrogen electrons recombine with nuclei, they emit red colored visible radiation.
• Nebular gas spectrum indicates composition similar to our sun, stars, and other ISM.
• Spectral line widths imply that gas atoms and ions have temperature around 8000K.
• Size information coupled with estimates of matter in our line of sight (as revealed by nebulae’s total light emission) ascertain nebular density - $10^8$ particles per cubic meter.

Through examination of interaction between dust and nebular gas, we see that dust lanes are part of the nebulae and not just dust in our line-of-sight.
**Another Name of Emission Nebulae**

Ionization state of an atom is represented by attaching roman numeral to its chemical symbol. e.g.

I  – neutral atom
II – singly ionized atom (missing one electron)
III – doubly ionized atom (missing two electrons)

Because *emission nebulae* are composed mainly of singly ionized hydrogen, they are often referred to as *HII regions*.

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**Dark Dust Clouds**

- More than 90% of space is free from emission nebulae and stars. It is simply dark.
- Within these dark voids lies --- *dark dust cloud*.
- They are typically bigger than our solar system and irregular in shape.
- They are much colder (only few 10s of Kelvin) and much denser than their surroundings.
- Made primarily of gas, but the dust they contain either diminish or completely obscure the light from background stars.

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**Dark Dust Clouds**

*Obscuration of visible light*

A dark dust cloud in the foreground obscures the stars of the Milky Way. The background stars on the periphery of the dust cloud are only partially obscured because the dust layer is thinner there. They appear red because the dust grains absorb blue light more effectively than red light.

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**Horsehead Nebula**

*Located in the constellation Orion*

Located in the constellation Orion

**Emission Nebula**

**Dark dust cloud**
**Dark Dust Clouds**

Absorption Spectra

We can learn about dark dust clouds by studying the absorption lines they produce in starlight that passes through them.

- The wide, intense lines are formed in the star's hot atmosphere.
- Narrower, weaker lines arise from the cold interstellar clouds.
- The smaller the cloud, the weaker the lines.
- The redshifts or blueshifts provide information on cloud velocities.

**21- Centimeter Radiation**

When no background star is available, how astronomers get information about dark dust cloud or interstellar medium?

Then, astronomers observe them by using the process known as the **21-centimeter line**.

- 21-cm line observation does not require light, only enough hydrogen to produce a detectable signal.
- Much gas in interstellar space consists of atomic hydrogen (HI form).
- Wavelength of 21-centimeter radiation is much larger than the typical size of interstellar dust particles, so they are not absorbed on their way to Earth and can be detected by radio telescopes.

**Molecular Gas**

- Forms molecular clouds (molecular hydrogen) and molecular cloud complexes.
- Only long wavelength radio radiation can escape from these parts of interstellar space.
- Can not use 21-cm observations because they are sensitive only to atomic hydrogen not to molecular H.
- Astronomers use radio observations of other "tracer" molecules (e.g. CO, HCN, ammonia, methyl alcohol etc.) to study these regions.
- Molecules are found only in the densest and darkest of interstellar clouds.
- Molecular clouds do not exist as distinct and separate objects in space, but found close to one another.

**Brief Review**

- What is interstellar medium?
- the matter between the stars.
- What are dark dust clouds?
- huge clouds made primarily of gas and some dust that absorb starlight and are cooler than their surroundings.
- What are molecular clouds?
- gas particles (molecules) that are in the dense interstellar regions.
- What are molecular cloud complexes?
- often, several molecular clouds are found close to one another, forming an enormous cloud millions of times more massive than the Sun.
- What are emission nebulae?
- glowing clouds of hot interstellar matter.